EXPEDIENT ENCAPSULATION: PROTECTECTIVE STRUCTURAL COATINGS

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ABSTRACT

The focus of this effort is to identify and evaluate the performance of non-toxic coatings that can be readily applied to the interior of any shelter to provide a protective barrier against chemical and biological agent threats. A proof-of-concept study was performed using a commercially available water-based strippable coating applied to the interior of a portable ‘office’ shed. The barrier polymer was assessed for its ability to significantly diminish the leakage rate of the structure when subjected to over-pressurization. The feasibility of the concept was clearly shown as the leakage rate was reduced by 69% over the uncoated structure.

INTRODUCTION

The goal of this effort is to develop the capability to provide expedient collective protection for any structure that does not have a pre-existing protective system. This will be accomplished through the application of coatings, either off-the-shelf or developmental, to the interior of a structure for the purpose of enabling over-pressurization of the “shelter” at an acceptable leakage rate. This effort will evaluate performance of non-toxic coatings for effective, on-demand application to interior structures for the purpose of providing sealant protection against threats related to weapons of mass destruction (WMD). The need is addressed for Expeditionary Collective Protection as described by the CBRN Capability Area Baseline Assessment in which encapsulation technologies are proposed to prevent or reduce individual collective exposures from CBRN threats, as well as protecting critical equipment.

The technical approach for the effort will include an initial proof-of-concept study that will assess the application of two select coatings on a large-scale (approximately 8’ x 8’ x 8’) shelter interior outfitted with a wide variety of construction materials such as dry wall, glass, ceiling tile, metal, canvas, and plastic. The first of these two coating proof-of-concept studies is the subject of this paper. Following the proof-of-concept demonstration, a more rigorous assessment of chemical interactions with the coating polymer and compatibility of several different coatings will be performed utilizing a bench-scale experimental chamber that is designed to simulate both the interior environment of a protected shelter and the surrounding outer atmospheric environment. Performance of coating formulations will be assessed based on ease of operation and efficiency of maintaining a sealed enclosure over time under a positive pressure environment. Other characteristics to be evaluated include resistance to permeation of the agent,

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **16 NOV 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Expedient Encapsulation: Protectective Structural Coatings**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Research Associates, Inc., 139 Barnes Dr., Suite 2, Tyndall AFB, FL 32403**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM001849, 2004 Scientific Conference on Chemical and Biological Defense Research. Held in Hunt Valley, Maryland on 15-17 November 2004 . , The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

polymer compatibility with different materials, vertical retention properties, associated human health hazards and capability of physical removal from material surfaces with minimal effort.

Successful completion of the effort will result in the identification of environmentally friendly coatings that can be effectively and rapidly applied as a protective barrier for military and/or civilian personnel occupying shelters. High payoff is anticipated if it is shown that a protective barrier can be applied to any shelter on-demand and achieves acceptable collective protection. Tools for delivering and applying protective coatings are perceived to range from use of a paintbrush, metering spray device, and/or a trowel. The use and application of a coating to an interior environment is also expected to complement use of a CB liner insert (M20A1) and/or plastic and duct tape. In a real world scenario, plastic sheeting and duct tape would be a practical first step to cover large gaps, ventilation ceiling ducts, doorways, and windows. Rapid application of the coating would then follow as a secondary protective barrier. Developmental coatings that offer advantages in affordability, logistics and tailoribility of the coating's chemistry will be considered in future work.

PROOF-OF-CONCEPT STUDY

The work presented here focuses on a proof-of-concept study with a commercially available coating applied to a portable storage building. The coating selected for use in the study was developed for radiological surface decontamination of nuclear facilities.[1] It is a proprietary encapsulating material that has excellent coverage properties and is readily removed for disposal. Testing was conducted to document the airflow required to pressurize a "typical" building that could be converted into a Collective Protection Equipment (CPE) shelter system. For this proof-of-concept study a commercially available storage shed made of aluminum and wood paneling was used. Although not a standard military facility, it was outfitted to replicate the common construction techniques found in many buildings (i.e. window, door, floor, wall, tile ceiling, electrical outlet and light fixture).

The first of two "proof-of-concept" studies was accomplished during the week of 19 July 2004 at Tyndall AFB, FL. The encapsulating coating was applied to the interior walls and ceiling of an 8' x 8' x 8' storage shed to approximately 45-50 mils, wet film thickness. The material contained 45% solids so the dry film thickness was calculated to be approximately 20-23 mils. Application of the coating was accomplished using a typical paint sprayer (Wagner, Model 770). Prior to coating the structure, the only attempt to seal leakage points was to cover the window and light fixture with plastic and duct tape. The coating was applied directly over this preparatory work. Some obvious gaps that remained after spraying were filled with coating using a standard paint brush. The coating was allowed to cure overnight prior to a series of leakage tests.

Leakage testing was performed by the 28th Test Squadron from Eglin AFB, FL to measure the airflow requirement for the test building after it was sealed with the encapsulating coating material. Test procedures used during the evaluation followed standard procedures outlined in the draft Test Operation Procedures (TOP) manual used at Eglin AFB.[2]

To summarize, leakage tests were performed by outfitting the shelter with a Minneapolis Blower Door™ as shown in Figure 1. The blower door's fan and measurements were controlled by Tectite v.3.1 leak rate software. The software controlled pressurization of the building in a range of 0.1 to 0.6 iwg and performed calculations of the leak rate based on air flow requirements. The recommended over-pressurization of a ColPro shelter is 0.3-0.5 iwg.[3] The shelter was outfitted with temperature, pressure and humidity gauges to accurately assess ambient conditions and to adjust the leak rate to standard conditions, 68ºF, 29.92 in Hg, and 50% relative humidity. The software used an algorithm that included sampling 100 data points at each pressure setting to correct for wind.

Following leakage tests of the coated building, large cracks that were not sealed completely by the application of the coating were sealed with duct tape and a new leakage test was accomplished. A pressurization test was then performed on the sealed building structure. This was accomplished by installing a surrogate door in the building and using an M28 blower unit to pressurize the structure. The surrogate door consisted of a sheet of Propex™ plastic that was held to the doorframe by the adjustable aluminum frame of the blower door system. The M28 blower hose was passed through a hole cut in the plastic and sealed with duct tape. After the M28 blower was turned on to pressurize the building structure, purge holes were cut in the plastic door to relieve pressure and the size adjusted until the building overpressure was steady at 0.5 iwg. The overpressure in the building was monitored with pressure transducers and a data acquisition system according to procedures listed in the Shelter Pressurization TOP used for this type of test.[4]

Figure 1. Proof-of-concept shelter with Minneapolis Blower Door™.

FUTURE STUDIES

Future studies will focus on examining a wide variety of coatings in bench-scale experiments to determine parameters that affect performance. Three critical performance issues will be addressed: 1) ability to maintain a seal under various conditions of pressure within an enclosed room, 2) operability and 3) impermeability to threat agents. The capability to physically remove the coating with minimal effort may be desired for some applications and will be considered.

RESULTS

A summary of the average results of the leakage testing is included below in Table 1. These values were calculated from the data from three trials at each test configuration. Average flow rate values were normalized for standard conditions (temperature of 68°F and barometric pressure of 29.92 in Hg) to yield flow rate in units of standard cubic feet per minute (scfm). Error estimates for these values were generally around 1 to 2% of the readings. The baseline leakage of the building at 0.5 iwg was 706.6 scfm. The leakage at this overpressure was reduced to 219.1 scfm after the coating was applied and allowed to cure overnight. The standardized data are graphically shown in Figure 2. Application of the coating resulted in a significant reduction (~69%) of the leakage of the building relative to the original baseline leakage at

0.5 iwg pressure. Following establishment of the coated structure leakage rate, visible cracks were sealed with duct tape and a new leakage rate was determined. The leakage was reduced an additional 47.0 scfm or 6.6%. This data is shown in Table 1 and graphically in Figure 2.

Also shown in Table 1 are the results of leakage isolation studies to determine potential critical leak points. The data representing leakage through two 3' x 3' squares (18ft^2) where the coating material was removed from the paneled walls does not show any significant change from the reestablished baseline. The data representing the leakage around the window shows that about 75 scfm or 11% of the building's total leakage, when pressurized to 0.5 iwg, could be attributed to leakage around the window. The window was exposed by cutting through the coating and the plastic around the window's frame and removing the protective material.

Table 1. Building Air Leakage Summary

	Average Calculated Leakage Values (scfm)					
Building Pressure (iwg):	0.10	0.20	0.30	0.40	0.50	0.60
Baseline Building Leakage	268.3	377.9	487.4	597.0	706.6	816.1
Sealed with Coating	84.7	127.9	162.6	192.9	219.1	244.3
% Reduction of Leakage:	68.4%	66.2%	66.6%	67.7%	69.0%	70.1%
Taped Cracks/Seams Leakage	53.5	88.8	119.3	147.1	172.1	196.8
% Reduction of Leakage:	80.0%	76.5%	75.5%	75.4%	75.6%	75.9%
Post-Pressurization Leakage*	56.3	87.3	123.2	143.6	170.8	No value
Change in Leakage:	2.7	-1.4	4.0	-3.5	-1.3	----
% Change Due to Pressurization:	5.1%	-1.6%	3.3%	-2.4%	-0.8%	----
New Baseline for Additional Tests	64.0	101.0	131.8	159.2	183.4	206.9
3' by 3' Sealant Squares Leakage	69.0	106.2	136.7	163.5	186.9	209.5
Net Leakage:	5.0	5.2	4.9	4.2	3.5	2.6
Windows Covering Leakage	97.6	149.6	192.1	229.3	261.9	293.2
Net Leakage:	28.6	43.4	55.4	65.9	75.0	83.7

*The blower door came loose from the doorway at the end of the post-pressurization test and invalidated the final reading and the overall test summary (because of software validation requirements). The values listed here are partial leakage readings from hand-written notes.

To evaluate the ability of the coating to withstand extended periods at typical ColPro overpressures of 0.5 iwg, a pressurization test was accomplished. The building was held at the 0.5 iwg pressure for a duration of 19 hours. After this time the pressure was still found to be at the baseline reading of 0.5 iwg. Blower door leakage testing was performed again to determine if the pressurization caused the sealant to rupture and cause additional leakage. The results from the first test showed that the absolute value of the percentage change in leakage (0.8%) was negligible. This change was well within statistical variation levels of the test equipment and/or factors such as variations in humidity levels that can cause swelling/contraction of the wood. Figure 3 graphically shows the leakage before and after the pressurization test was completed. The graph clearly shows that the change in leakage rate was insignificant. The coated "shelter" maintained its integrity following pressurization.

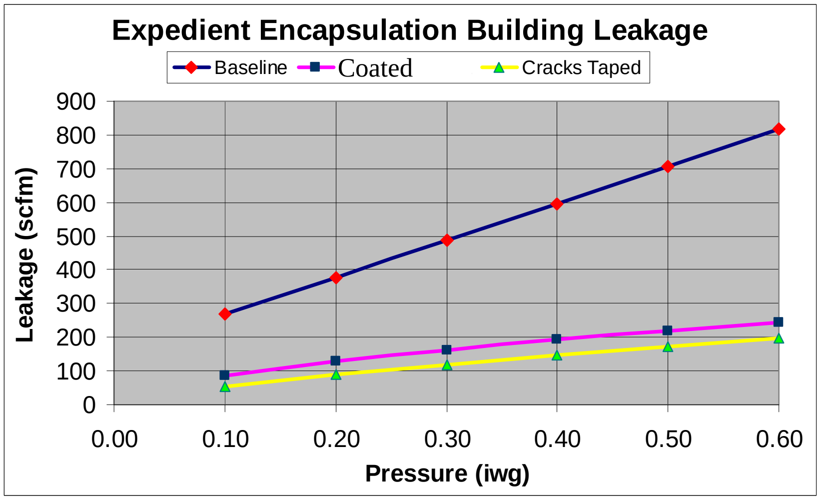

Figure 2. Baseline vs. sealed building leakage values.

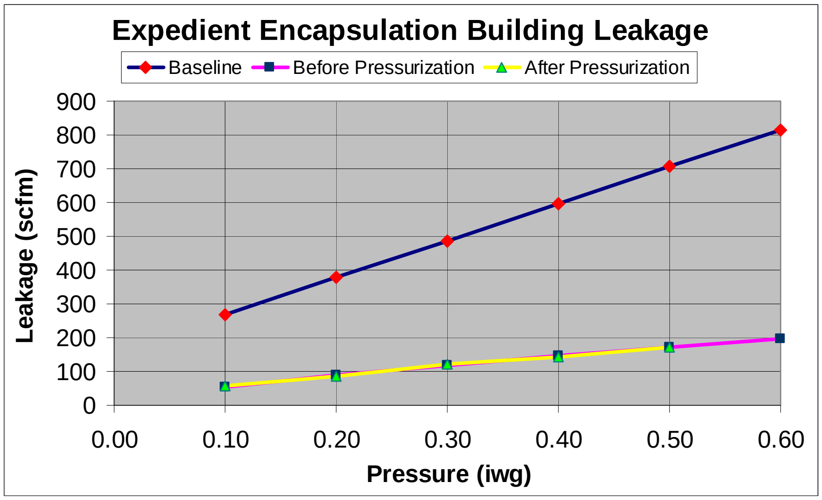

Figure 3. Leak rate data before application of coating (Baseline), after application of coating and after pressurization of the coated building overnight at 0.5 iwg.

CONCLUSIONS

This preliminary work has shown that application of encapsulating coatings to interior walls and ceilings of a structure is a feasible and expedient means of sealing pressure leak points. The baseline leakage rate of the uncoated shelter, pressurized to 0.50 iwg, was significantly diminished after coating the interior walls and ceiling of the shelter. The most vulnerable areas were ceiling tiles and seams and the results show that these were effectively sealed after coating. After taping some obvious cracks left behind after coating the leakage rate was additionally reduced to 172.1 scfm at 0.5 iwg overpressure (>75% reduction). At this leakage rate, an M28 filter unit is adequate for use to pressurize the building and provide additional filtered airflow rate for purging purposes.[5]

The contribution of one window was less than expected accounting for only 11% of the leakage measurements. The coated shelter was able to maintain over-pressurization overnight with no significant change in leakage measured upon post-pressurization. This suggests that the coating was not breached and that the expedient coating concept will be able to maintain its integrity over an extended period of time.

Additional studies are necessary to evaluate characteristics such as permeability of the coating to chemical intrusion, compatibility with different materials, vertical retention properties, application requirements, cost, and transportability. The proposed encapsulation technologies presented here are not intended to replace existing fixed and transportable COLPRO systems, but rather add a new capability that can expediently provide collective protection using existing facilities or shelters where no COLPRO system exists.

ACKNOWLEDGEMENTS

The authors extend their appreciation to Vic Arca, Scott Matheson, and Terese Anderson for supporting leakage rate tests during the study.

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